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§11. X-ray Spectral Analysis on Electron Interatcion with Highly-Charged Xe Ions

Kato, D., Nakamura, N. (Univ. of Electro-Commun.), Ohtani, S. (Univ. of Electro-Commun.)

Charge state distribution of Xe ions in an electron-beam-ion-trap (EBIT) was studied based on coupled rate equations for ion population density and temperature. A synthetic X-ray spectrum of highly charged Xe ions was compared with an experimental spectrum measured at the Tokyo-EBIT. Observed lines have been identified and the wavelengths have been determined experimentally for elements of Z=50-56[1].

The X-ray transition excited by a 60 μm-diam electron beam was measured at the Tokyo-EBIT with a flat crystal spectrometer[2]. Two types of crystal were used according to objective wavelength; one was LiF(200) with an area of 120x50 mm^2 and another was Si(111) with an area of 120x70 mm^2. The spectrometer was operated in vacuo (10^{-7} torr) to avoid absorption by air. Fig. 1 shows an example of the experimental and synthetic X-ray spectra for Xe ions.

The synthetic spectrum was obtained using atomic data of the HULLAC code and a given charge state distribution. The charge state distribution was predicted using a set of coupled rate equations for ion population densities and temperatures. The ion-loss rate was approximated by a formula for the magnetic-mirror configuration of a uniform magnetic field[3]. In the present calculation, we assumed that neutral Xe gas was injected continuously into the trap so that the neutral density was maintained at 10^5 cm^{-3}. Charge exchange (CX) with the neutral Xe atoms may affect the charge state distribution to some extent. However, it was neglected in the present calculations, since the CX rate was estimated to be several orders of magnitudes smaller than the ion-loss rate for the neutral density of 10^5 cm^{-3}. In Fig. 1(b), four electric-dipole lines of the Ne-like ions are indicated as 3D, 3E, 3F, and 3G. Their upper levels are $(2p_{3/2}^{-1}3d_{5/2})_{J=1}$, $(2p_{3/2}^{-1}3d_{3/2})_{J=1}$, $(2p_{1/2}^{-1}3s)_{J=1}$, and $(2p_{3/2}^{-1}3s)_{J=1}$, respectively. Two electric-quadruple lines E2M and E2L and one magnetic-quadruple line M2 have upper levels of $(2p_{3/2}^{-1}3p_{1/2})_{J=2}$, $(2p_{3/2}^{-1}3p_{1/2})_{J=2}$, and $(2p_{3/2}^{-1}3s)_{J=2}$, respectively. Lower levels for those lines are of the ground state $(2p^6)_{J=0}$.

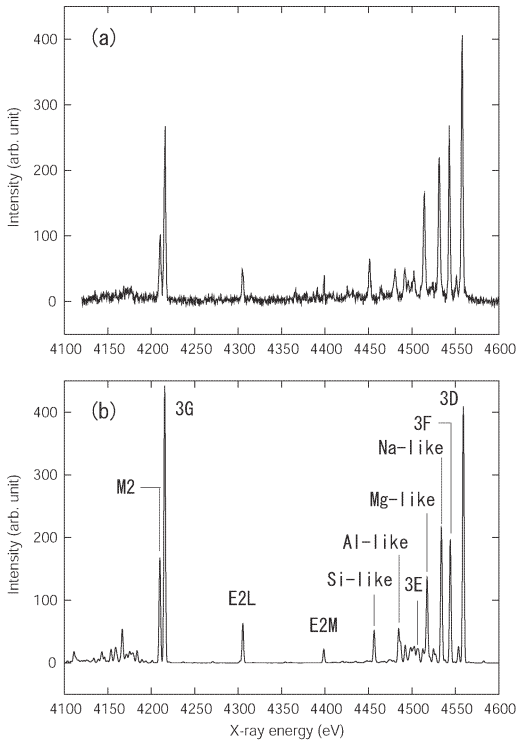

Fig. 1: (a) Experimental X-ray spectrum of Xe ions measured at the Tokyo-EBIT. Electron beam energy ≈ 5540 eV (below the ionization energy of the Ne-like Xe ion), electric current ≈ 97 mA, magnetic field strength in the drift tubes ≈ 4 T, and axial potential well ≈ 100 eV. (b) Synthetic spectrum convoluted using the Gaussian distribution function with a full-width-at-half-maximum of 2 eV. 3D, 3E, 3F, 3G, E2M, E2L, and M2 lines are of Ne-like ions.

References

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